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Applicability of Machine Learning towards development of Patient Centered Decision Support System to Palliative Care Settings

Hannibal Hyacinth Lobo[a,*], Krishna Prasad K[b], Vishal Dattana[c]

[a]*Research Scholar, Srinivas University, Mangalore, Asst. Professor, St Agnes College, Mangalore*
[b]*Professor, Srinivas Institute of Engineering and Technology, Srinivas University, Mangalore*
[c]*Director and Assistant Professor, Oman College of Management and Technology, Oman*

Abstract

Developing systems for assisting in the care of palliative patients requires an understanding of providing relief from distressing symptoms to ease suffering and improve the Quality of Life. To assess the applicability of Artificial Intelligence techniques to Palliative care settings, it is important to understand methods suitable for symptom care and management such that they provide relief from distress due to the life-limiting illness. With rapid advancements in Artificial Intelligence, developing automated healthcare systems for patient care has revolutionized personalized care which is of significance in palliative care settings. This article summarizes the existing literature which suggests the need for improved end-of-life care for a better Quality of Life and the implementation scenarios where AI is integrated in healthcare systems to assist the palliative care team in decision making and thus enhance patient care.

Keywords: palliative care; artificial intelligence; symptom management; machine learning; natural language processing; deep learning; Quality of Life

1. Introduction

The World Health Organization (WHO) in its resolution of 2014 states that palliative care service is a part of the health care system worldwide. Palliative Care (PC) is a mechanism of care intended for people with life-limiting illness, or can be briefly stated as a people-centered health care service. Care is intended to alleviate suffering from physical, social, psychological and even spiritual issues. PC generally commences when a life-limiting illness is

E-mail address of authors: *hannabelalva@stagnescollege.edu.in, krishnaprasadkcci@srinivasuniversity.edu.in, vdattana@ocmt.edu.om

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diagnosed, and continues in parallel with the medical treatment that is directed towards the illness. To enable uniform access to palliative care services globally, a number of tools for symptom and Quality of Life (QoL) assessment have been developed and the emphasis is to incorporate palliative care into the basic health care [1]. The WHO estimates that among 40-60% of the global deaths, palliative care is essential. The illnesses identified in these patients include AIDS, cardiovascular, cancer, dementia, drug-resistant tuberculosis, kidney failure, liver disease, respiratory disease, and rheumatoid arthritis. Two of the symptoms most often expressed by patients are moderate-to-severe pain and difficulty in breathing and these generally increase with the progression of the disease. Opioid medication is an essential treatment for pain and is observed to ease other distressing physical symptoms. Factors such as anxiety and depression add to the existing stress and adequate measures need to be taken to ease them [2][3].

With advancements in the domain of Artificial Intelligence (AI), healthcare providers are equipped with additional tools in clinical practice to assist in enhanced decision making. Research has implemented Machine Learning (ML) and deep learning techniques to predict the mortality of patients irrespective of disease within 3-15 months. ML approaches have been developed to predict the 30-day mortality of cancer patients undergoing chemotherapy as well as predict the survival in patients with metastases. To assist in identifying desirable attributes of care in end stage liver disease patients, and to cluster liver malignancy patients according to survival probability, supervised and unsupervised ML techniques are incorporated. Patient reported symptoms provide valuable insights into symptom care and natural language processing and machine learning have been used to extract symptom documentation and identify goals of care from electronic health records of cancer patients [4]. Monitoring routine data related to health parameters helps assess the provided care and suggest improvements in patient care [5][6]. Research is find mechanisms to incorporate AI techniques in palliative health care to assist decision making and some of the research carried out is reviewed and this paper discusses the recent implementations to the palliative care domain.

2. Research Objectives

- To review the importance and need of palliative care through recent studies.
- To present and discuss the relevance of machine learning methods in palliative care settings through reviewed papers.
- To discuss some opportunities and challenges in applying Artificial Intelligence techniques to palliative care.

3. Literature Review

Research suggests that well planned symptom relief in cancer patients has shown improvement in the QoL of both the patients and their caregivers and better conformity to the treatment provided [7]. In the aging population, the severity of symptom care increases and highlights the need for an integrated approach to symptom care in addition to the routine treatment addressing the illness. The four common symptoms experienced by cancer patients are pain, nausea, fatigue and breathlessness, and these sometimes get under-treated or poorly managed highlighting the need for improved symptom care in addition to the treatment addressing the illness. To assess the level of different symptoms, patient-reported outcome measures (PROMs) are incorporated with routine treatment, and these have proved beneficial to symptom assessment and treatment plan. Using the symptoms and concerns identified through PROMs, the palliative care needs of patients are easily identified. Integrating technology to implement PROMs has proved to be a key component to assist with routine clinical care. Remote monitoring devices for Asthma patients, use of touch screen devices and electronic monitoring of symptoms in patients have improved the quality of life with fewer hospital emergencies, improved survival and emotional care. [8][9].

Diagnosing and monitoring the symptoms and the prognosis is the most critical element in improving the QoL and overall well being of cancer patients. The severity of pain has a direct impact on the QoL and necessitates pain management principles to be implemented [9][10]. To facilitate more accurate decision making, physicians and patients use Prognosis prediction models. Continuing palliative chemotherapy which is ineffective at end of life increases the chances of hospitalisations due to adverse events and in turn decreases the QoL. Hence predicting the prognosis is vital for improved end of life care. Clinical Prediction of survival is based on the specific clinician and is a subjective opinion and hence it is important to develop objective prognosis prediction models using prognostic factors which include symptom and laboratory data [11].

The bioinformatics domain has contributed to the study of Machine Learning in palliative care settings for developing prediction models [10][11][12]. Artificial Neural Networks (ANNs), Bayesian Networks, Support Vector Machines (SVM), and Decision Tree have been used to model predictive systems to understand the progression and treatment outcome of cancer patients. ANNs and Decision trees are suitable for classification or pattern recognition, SVMs are applied for prediction and prognosis while classifiers using Bayesian Network are used to compute the probability estimation instead of prediction. [10]. With the limited availability of data in palliative patients due to restricted invasive procedures, it is important to retrieve symptom data from health records and perform research in this domain [11][12]. Electronic Health Records (EHR) contain valuable information on patient clinical care, symptom details, treatment plan and demographic data. Data from health records are used to develop ML models to identify specific attributes of health issues, detect ailments, identify features that cause changes in symptom levels such as pain at end of life, predict the trajectory of the outcome of care, identify risks of outcomes and hence improve clinical decision making and provide for individualised patient centered interventions [5][13].

Table 1 highlights the research conducted in the domain of palliative care focusing on the importance of symptom management to provide better Quality of Life in terminally ill patients.

Table 1. Importance and need of palliative care from routine health care data.

Sl. No.	Authors	Importance and Need
1	Henson, L.A., et al. in 2020	● Good symptom management improves patient QoL and better survival advantages in Palliative care. ● Need for integrated symptom management in addition to regular treatment of illness.
2	Kwekkeboom, K. L. in 2016	● Cancer symptoms can form clusters such as pain, fatigue and sleep disturbance form a cluster, PCA has been used to identify clusters. ● Clinical practice can be enhanced by targeting a symptom cluster with a single intervention for the symptom cluster in Palliative Care settings.
3	Scarborough, B. M., et al., in 2018	● Necessary to assess and manage pain and other symptoms regularly to improve QoL in palliative care. ● 64% of advanced cancer patients report pain during the illness ● Pain is inadequately treated in cancer patients and options available to treat pain need to be incorporated
4	Chang, V. T., et al. in 2017	● Core elements of Palliative care should be to manage symptoms and align treatment plan with the patient's desires. ● Patient centered approach based on patients reported symptoms.

		● Periodic symptom assessment helps improve treatment plan by monitoring response to symptom interventions.
5	Davies, J. M., et al. in 2016	● Collecting health care data routinely through Patient Centered Outcome Measures helps evaluate plan of care and enables improvement in symptom management and end of life care research ● Avoids the challenges of data collection ● Natural Language Processing is used to analyse free-text from patient records
6	Yang, B., et al. in 2020	● A pain management study that recruited 92 cancer patients ● Pain is a major factor for decrease in QoL and increases the risk of anxiety and depression ● It is a multi-dimensional symptom that requires individualized therapy for pain control
7	Rosenwax, L., et al. in 2016	● Population included death records of 2 years ● Associations between demographic, social and disease conditions identified
8	Peyton, L., et al. in 2012	● Implementing an information system to improve delivery of palliative care ● Routinely assessing pain and other symptom data of remotely monitored patients demonstrated improved ability of care
9	Ghoshal, A., et al. in 2022	● 233 palliative care centers registered with IPAC included in the survey ● Palliative care is not reaching the required levels in India with challenges to morphine access and assessment of symptom care
10	Gaikwad, A., et al., in 2022	● Need for development of Palliative care in India ● Implementing palliative care research at ground level is required ● Recognizing and treating physical symptoms such as pain, nausea, shortness of breath, anxiety, depression ● Low cost quality centered pain management should be accessible to the marginalized
11	Hasson, F., et al., in 2020	● Need for the patient to be considered as a dominant factor when performing palliative care research ● Gaps observed in priorities related to QoL and symptom management
12	Saxena, A. K., et al., in 2019	● A beneficial and rational option for treating advanced stage cancer is palliative care and pain management ● Breathlessness, nausea, constipation, fatigue, and delirium are to be treated ● Access to availability of opioids and other medicines is an issue in India
13	Verkissen, M. N., et al. in 2019	● Study population of 1739 patients from 30 PC centres ● Early identification of symptoms and their treatment addresses providing a stable QoL ● Anxiety, appetite loss, depression, dyspnea, fatigue, nausea and pain are symptoms that impact QoL

		● PC stabilises or slows symptom progression
14	Tai, S. Y., et al., in 2016	● Palliative care decreases symptom severity ● Study population of 824 patients observed pain as the most common symptom in advanced cancer followed by anorexia and constipation
15	Bendinger, T., et al., in 2016	● There is a correlation between Pain and other psychological factors ● Validated scales are useful to measure the multidimensional facets of pain
16	Matzka, M., et. al., in 2018	● Symptom clusters and psychosocial aspects impact QoL ● Study population of 304 cancer patients to assess symptoms and QoL ● Fatigue-pain, anxiety-depression, nausea-vomiting clusters identifies
17	Edge, R., et al., in 2020	● Relationships exist between pain, depression, anxiety and QoL ● Physical QoL is found to be associated with psychological QoL ● Study demonstrates the need to quantify QoL considering both physical and psychological symptoms
18	Omran, S., et al., in 2017	● Symptom control is important to provide optimal QoL ● Pain, lack of energy, lack of appetite, dry mouth, drowsiness and shortness of breath are the most prevalent symptoms ● Four symptom clusters identified
19	Hagarty, A. M., et al., in 2020	● Disease trajectory in cancer patients impacts pain, need to recognize daily pain levels ● Demographic and clinical factors are associated with increased pain ● Study observed the proportion of daily pain in the last 30 days of life
20	Hammer, M. J. et al., in 2022	● Pain, fatigue, depression and sleep disturbance co-occur in oncology patients ● Multimodal interventions needed to reduce symptom burden and improve QoL

Table 2 highlights the different areas where Machine Learning models have been implemented and the features used to build the models.

Table 2. Applicability of Machine Learning methods to palliative care settings

Sl. No.	Authors	Importance and Need
1	Rahman et al. in 2018	● Assessing and predicting users pain volatility levels ● Patient demographics and daily clinical features ● Logistic regression, LASSO Random Forest, Support Vector Machine, K-means clustering
2	Liu et al. in 2018	● Automatic pain assessment using raw face images ● Linear Regression, Naive Bayes, Logistic Regression, Support Vector Machine, Gaussian Processes, Random Forest, Genetic algorithms, Artificial Neural Networks

3	Avati et al. in 2017	● Predict patients who are most likely in need of Palliative care and predict mortality within 12 months ● Patient demographics, Electronic Health records for clinical features ● Deep Neural Network
4	Yang et al. in 2018	● Predict pain scores in Sickle cell disease patients ● Patient physiological features and pain score ● Multinomial Logistic Regression, K-Nearest Neighbors, Support Vector Machine, Random Forest
5	Jia et al. in 2016	● Predict pain scores in Sickle cell disease patients ● fatigue, nausea, drowsiness, depression, shortness of breath, appetite, well-being, anxiety, pain ● Markov multistate model
6	Soltani. M., et al. in 2022	● MIS to identify patients' need and effectively plan care ● Demographic, PPS, health service history data ● LSTM
7	Matsangidou et al. in 2021	● Machine learning to diagnose, classify, and manage pain. ● Logistic Regression, K-Nearest Neighbors, Support Vector Machine, Random Forest, Decision Tree
8	Shimada et al. in 2021	● Predict patient non visible symptoms from background data and visible symptoms ● Clinical details, ECOG, appetite, nausea, constipation, edema, sleep disturbance ● Decision Tree
9	Windisch et al. in 2020	● AI for symptom management in Palliative care ● Timing the involvement of palliative care improves QoL
10	Yang. in 2020	● To predict numeric pain score ● Physiological, body movement measures ● Ridge, LASSO, Gaussian, SVM
11	Sivanandan et al. in 2021	● Use of digital PROM for remote symptom monitoring ● Enable remote monitoring of patients
12	Papachristou et al. in 2018	● Predicting course and severity of symptoms using computational tools to provide personalized timely interventions ● Three interrelated symptoms are depression, anxiety, and sleep disturbance ● Support Vector Regression, Neural Networks
13	Lee. J., et al. in 2019	● To classify clinical pain states and predict pain intensity for chronic low back pain ● Multimodal brain images and autonomic markers ● Support Vector Machine, Neural Networks
14	Al-Eidan. M., in	● Automated pain Recognition

	2020	● Physiological Signals, Speech, Facial Expressions ● CNN, RNN, LSTM, MT-NN
15	Beeksma. M., et al. in 2019	● Improvement is quality of final phase of life through Advance care planning ● Electronic Medical Records of patients ● NLP, LSTM
16	Hur. S., et al. in 2021	● Delirium prediction model within 24 hours of ICU admission ● Physiological data ● Random forest, XGBoost, Logistic Regression, Deep Neural Network
17	Awad. A., et al. in 2017	● Prediction of early mortality in ICU patients ● Demographic, vital signs and Physiological data ● Random forest, Decision Tree, Naive Bayes, SVM
18	Lee J. in 2017	● Patient specific predictive model for 30-day mortality - Intensive Care Unit care ● Demographic and vital health parameters ● Logistic Regression, Decision Tree, Random Forest
19	Motwani. M., et al. in 2017	● Prediction of mortality within 5 years in patients with coronary artery disease ● Symptoms and cardiovascular risk factors, CCTA data ● ML ensemble boosting (Logit-Boost)
20	Shim. J.G., et al. in 2021	● Predict risk of chronic lower back pain ● Demographic and clinical data ● Logistic Regression, K-nearest neighbors, Naïve Bayes, Decision Tree, Random Forest, Gradient Boosting Machine, Support Vector Machine, Artificial Neural Network
21	Moser. E.C., et al. in 2020	● Importance of AI modelling with clinical practice for patient centered care, symptom management and risk prediction ● Patient Clinical data ● AI driven predictive tools
22	Yang. Z., et al. in 2018	● Clinical Intelligent decision system using CNN to extract semantic features from EHR assisting in diagnosis ● Hypertension, Diabetes, COPD, Gout, Asthma, Gastritis, Arrhythmia ● Stochastic gradient descent, SVM, Naive Bayes, Logistic regression, KNN, CNN
23	Broek-Altenburg. E., et al. in 2021	● NLP to extract text data from audio palliative consultations and follow-up questionnaires to identify moral values and beliefs ● NLP, Poisson Regression
24	Sandham et al. in 2022	● To identify five phases in palliative status using symptoms ● Demographic, routine patient reported symptom data ● Neural Networks, Naïve Bayes, Decision Tree, ID3, Logistic Regression, Random forest

25	Jung. K., et al. in 2019	• Predicting mortality within 1 year • Demographic, Clinical encounters, diagnoses • Logistic Regression, Gradient boosting
26	Francoeur, R. B., in 2015	• Pain, fatigue, and insomnia form a cluster • Sequential Residual Centering multiple Regression
27	Gkikas, S., et al., in 2023	• Optimal pain management to reduce suffering and prevent functional decline • Demographic, Clinical data, pain scales • Deep learning
28	Nagireddi, J. N., et al. in 2022	• Automated decision system for pain assessment using facial image analysis • Facial Expression images • Machine Learning, NLP, Deep Learning, Statistical Analysis

Table 3 discusses the opportunities for applying Artificial Intelligence techniques to interdisciplinary palliative care settings. It identifies reliable data sources for data mining and machine learning opportunities.

Table 3. Availability of data for opportunities in applying AI techniques for palliative care

Sl. No.	Authors	Importance and Need
1	Gensheimer M.F., et al. in 2019	• Electronic Medical Records - provider note text, vital signs, medication orders, and diagnosis details
2	Courtright. K.R., et al. in 2019	• Electronic Health Records - patient Characteristics, diagnosis
3	Bush R.A., et al. in 2018	• Electronic Health Records - Clinical Decision Support using care documentation, PROMs
4	Forsyth A.W., et al.in 2018	• Electronic Health Records - text in electronic health records notes
5	Siemens W. et al., in 2020	• Health Records - Questionnaires - physical, psychosocial symptoms and QoL measure
6	Barton. C., et al. in 2019	• Electronic Health Records - Heart rate, respiratory rate, temperature, blood pressure
7	Parikh R. B., et al. in 2022	• Electronic Health Records, Patient Reported Outcomes - laboratory findings, demographics, diagnosis details
8	Cary Jr, M. P., et al. in 2021	• Health Records - Patient assessment data - sociodemographic, clinical factors
9	Lee. R. Y., et al. in 2021	• Electronic Health Records - notes on goals of care discussions
10	Curtis. J.R., et al. in 2018	• Electronic Health records - Clinical and symptom data
11	Vartiainen, P., et al., in 2019	• Validated HRQoL instruments - Symptom data
12	Lamas, D., et al. in 2018	• Electronic Health records - Advance Care Planning using demographic and Clinicals

4. Recent related studies and enhancements possible

Healthcare data that is routinely collected provides increasing opportunities for valuable insights to be obtained using Artificial Intelligence techniques and data driven methods [74]. Research studies have shown that incorporating AI into health care has helped provide for less aggressive care in ICU admissions, administering a ventilator or resuscitation procedure at end of life [11][75] [76] [77]. Applications of Machine Learning in pain care research are limited due to the availability of data. The availability of a limited number of subjects for these studies or the maintenance of related knowledge bases are some limiting factors observed [12]. One of the six domains that addresses improving quality of healthcare is patient-centeredness. In order to provide a holistic approach to healthcare, timely patient centered care is essential which can be provided through monitoring patient reported symptoms and implementing ML models for prediction and risk identification [78][79][80].

5. Research Gap

With advances in technology and the increase in research suggesting the suitability of incorporating Artificial Intelligence methods to varied domains, many researchers have incorporated machine learning models to carry out interdisciplinary research. Advances have been supported with availability of significant training and testing datasets. In addition, automation tools and ML applications have been developed for improved decision making. With an increase in the availability of clinical data, images and free text noted in Electronic Health Records, healthcare research can benefit in providing quality care. Palliative care research suggests symptom management to be of significant value in providing individualized interventions. Clinical records provide valuable insights and these can be extracted using suitable ML models using routine symptom data. Patient or caregiver-reported symptom data can be used to develop prediction models for symptom trajectory and identify symptom clusters that could benefit from a single intervention.

6. Research Agendas Based on Research Gaps

The following are suggestions that could benefit in providing improved Quality of Life through patient Centered palliative care:

- Routine symptoms can be noted and Exploratory Data Analysis could identify relations between symptoms and symptom clusters.
- Feature extraction and feature selection methods could assist in identifying relevant features and reduce computations.
- Symptoms such as pain and depression can be predicted for a specific window period to assist in the treatment plan.
- Different AI algorithms can be implemented to attain higher accuracy in predictions.

7. Conclusion

This review aimed at providing details on the importance of palliative care as a human right and the applicability and use of Artificial Intelligence techniques that provide decision support in planning treatment for end of life care. Using readily available clinical data from patient records to implement Machine Learning models will help care providers in providing timely interventions for terminally ill patients and enhance their Quality of Life.

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